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SOME THERMOPHYSICAL PROPERTIES OF A GRANODIORITE ROCK FROM NEVADA TEST SITE

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APRIL, 1978

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(For submission to AECL)

Project MRP-4.3.2.4.02

Thermal and Mechanical Properties of Host Rocks

11 pp

MINERALS RESEARCH PROGRAM

MINERAL SCIENCES LABORATORIES
REPORT MRP/MSL 78-8 (CF)

COPY NO. 01

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MINERAL SCIENCES LABORATORIES
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SOME THERMOPHYSICAL PROPERTIES OF A
GRANODIORITE ROCK FROM NEVADA TEST SITE

by

V.V. Mirkovich*

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ABSTRACT

Thermal diffusivity and linear thermal elongation of a granodiorite rock from the Nevada test site were measured as a part of a cooperative study to evaluate the suitability of different rock masses for storage of nuclear waste. It was found that the thermal diffusivity of this specimen was, particularly at lower temperatures, higher than that of a previously studied granodiorite specimen. Comparison of thermal elongation data revealed that at lower temperature the Nevada specimen had higher values while at the top temperature (500°C) it was lower by some 18% than the values obtained on the previously measured specimen.

Calculated high temperature thermal piercing rate indicates that the thermal spallability of this rock could be high, - an undesirable characteristic for rock repositories of nuclear waste.

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INTRODUCTION

As a part of the cooperative effort to select rock masses for storage of nuclear waste a sample of granitic rock from a Nevada test site (U.S.A.) was submitted to CANMET by Lawrence Livermore Laboratory (L.L.L.), California, U.S.A. for determination of thermal diffusivity in unconstrained conditions in the temperature range of 25° to 500°C. The sample comprised four 25-mm diameter, 25-mm high cylinders, a hand specimen and a thin section. Petrographic analysis by Soles⁽¹⁾ of the hand specimen and the thin section revealed the rock to be a granodiorite. The density of the hand specimen is 2.60 g/cm³. Its composition is shown in Table 1.

TABLE 1
Mineral Composition of Granodiorite Sample

Mineral	Content, %
Plagioclase (An ₃₀₋₃₅)	46 .
Orthoclase	13
Quartz	22
Biotite	14
Muscovite	4
Magnetite	1
Accessories	<1

In order to obtain a more complete characterization, linear thermal elongation of this specimen was determined in the 25° to 500°C range. Thus both thermal diffusivity and linear thermal elongation results can be compared with recently published data.

EXPERIMENTAL

Thermal diffusivity was measured by the method developed in this laboratory and described in detail previously^(2,3). In essence, the specimen in the experimental configuration is made to represent part of an infinite cylinder in which there is only radial heat flow. The temperatures are measured in one radial plane, at the centre and at a point near the surface of the cylinder. Measurements can be performed in either a transient or a periodic mode.

In the transient mode the initial temperature throughout the specimen is zero and the surface temperature is a linear function of time. With constant-rate heating of the surface, the temperature differential is plotted until it reaches a maximum. An equation relates the increase in the dimensionless temperature differential to a dimensionless factor which includes thermal diffusivity, time and the diameter of the cylinder.

In the periodic mode the surface temperature is a harmonic function of time. The time interval needed for the heat wave to penetrate from the near-surface measuring point to the centre is related to thermal diffusivity.

Because the gain in the accuracy of measurements, which would have been achieved by performing the measurements in both modes, was not considered for this case to be significant and because the measurements in the transient mode could be completed in a considerably shorter time than in the periodic mode, all measurements were made in the transient mode. The cylindrical rock specimens were used (after drilling appropriate thermocouple holes) as supplied by the Lawrence Livermore Laboratory.

Linear thermal expansion measurements were made in a commercial dilatometer employing fused quartz media⁽⁴⁾. Rock specimens in form of rectangular rods, 50.8 x 6.34 x 6.34 mm, were prepared from the hand sample.

RESULTS AND DISCUSSION

The thermal diffusivities of the two granodiorite specimens are shown in Figure 1. The circles and crosses indicate the measured points for rock specimens 1 and 2, respectively. The curves were fitted to the data by the least square method. Each curve can be represented by an equation of the type:

$$\alpha = a_0 + a_1 t + a_2 t^2$$

where α is thermal diffusivity in cm^2/sec and t is temperature in $^{\circ}\text{C}$. The constants and standard deviations are given in Table 2.

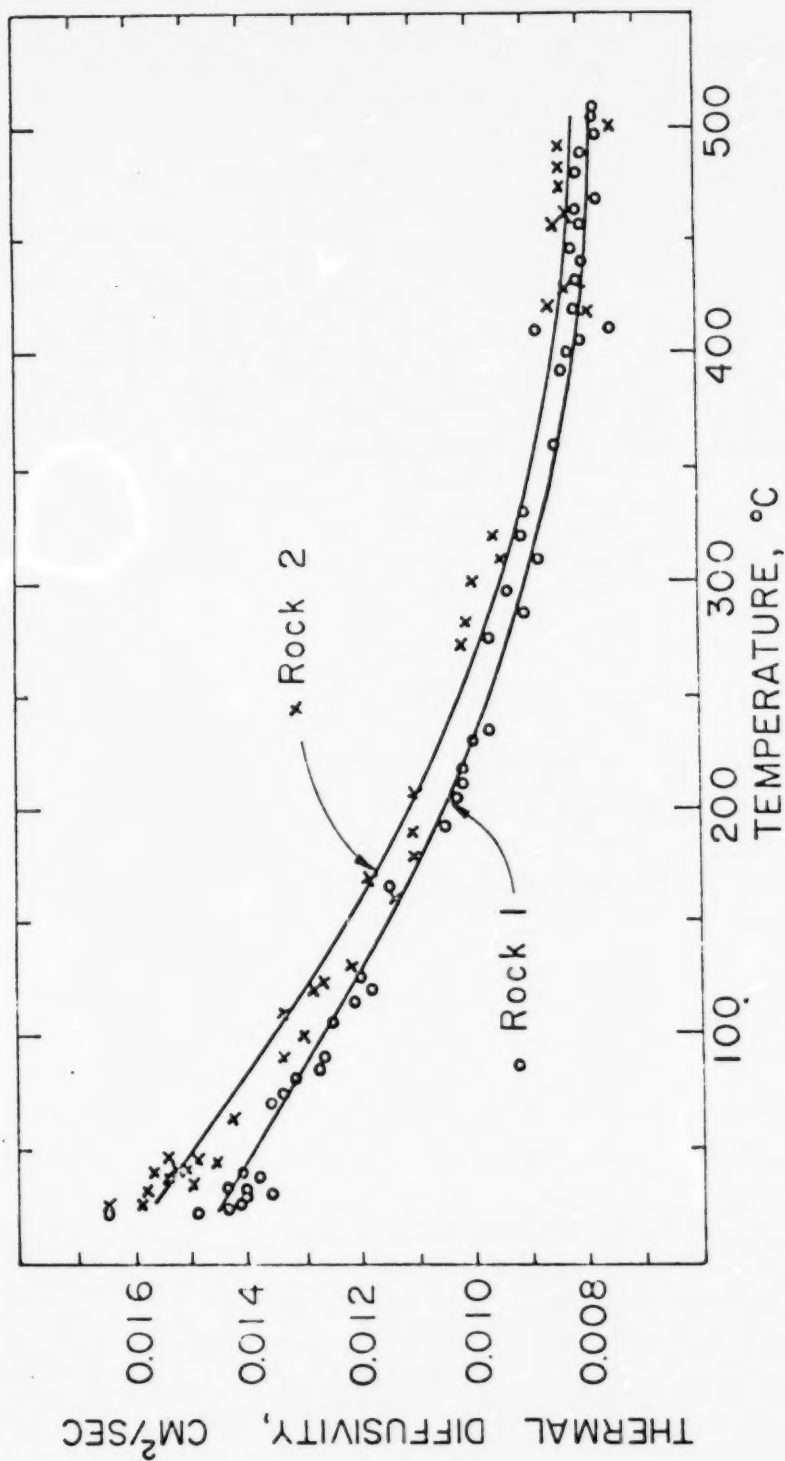


Figure 1. Thermal diffusivities of two granodiorite rock specimens from Nevada test site.

TABLE 2
Values of Constants for the Polynomial
Equation and Standard Deviation

	a_1	a_2	a_3	Standard deviation, α
Rock No. 1	1.524×10^{-2}	-2.947×10^{-5}	2.972×10^{-8}	0.000286
Rock No. 2	1.654×10^{-2}	-3.401×10^{-5}	3.476×10^{-8}	0.000201

The difference of about 5 per cent between the thermal diffusivities of the two rock specimens at higher temperatures cannot be considered significant. It could have been caused by a slight difference in the time response of the thermocouples as well as by small variations in the positioning of thermocouple holes and it is therefore within the accuracy limit of the measuring system. However, the difference of 8 per cent between the two thermal diffusivities measured at room temperature indicates that there is a small, but nevertheless actual variation in the textural and/or mineralogical composition between apparently identical specimens.

It is of interest to compare the present thermal diffusivity values with the data obtained previously on similar rocks. In Figure 2, Curves 1 and 2 are the results of this study. Curve 3 represents the thermal diffusivity of a granodiorite specimen measured by Mirkovich⁽⁵⁾ in an earlier investigation. The thermal diffusivity of a different granodiorite rock was measured by Hanley *et al.*⁽⁶⁾ and it is shown by Curve 4.

The higher thermal diffusivity of the granodiorite specimen from L.L.L. could be attributed to its higher quartz

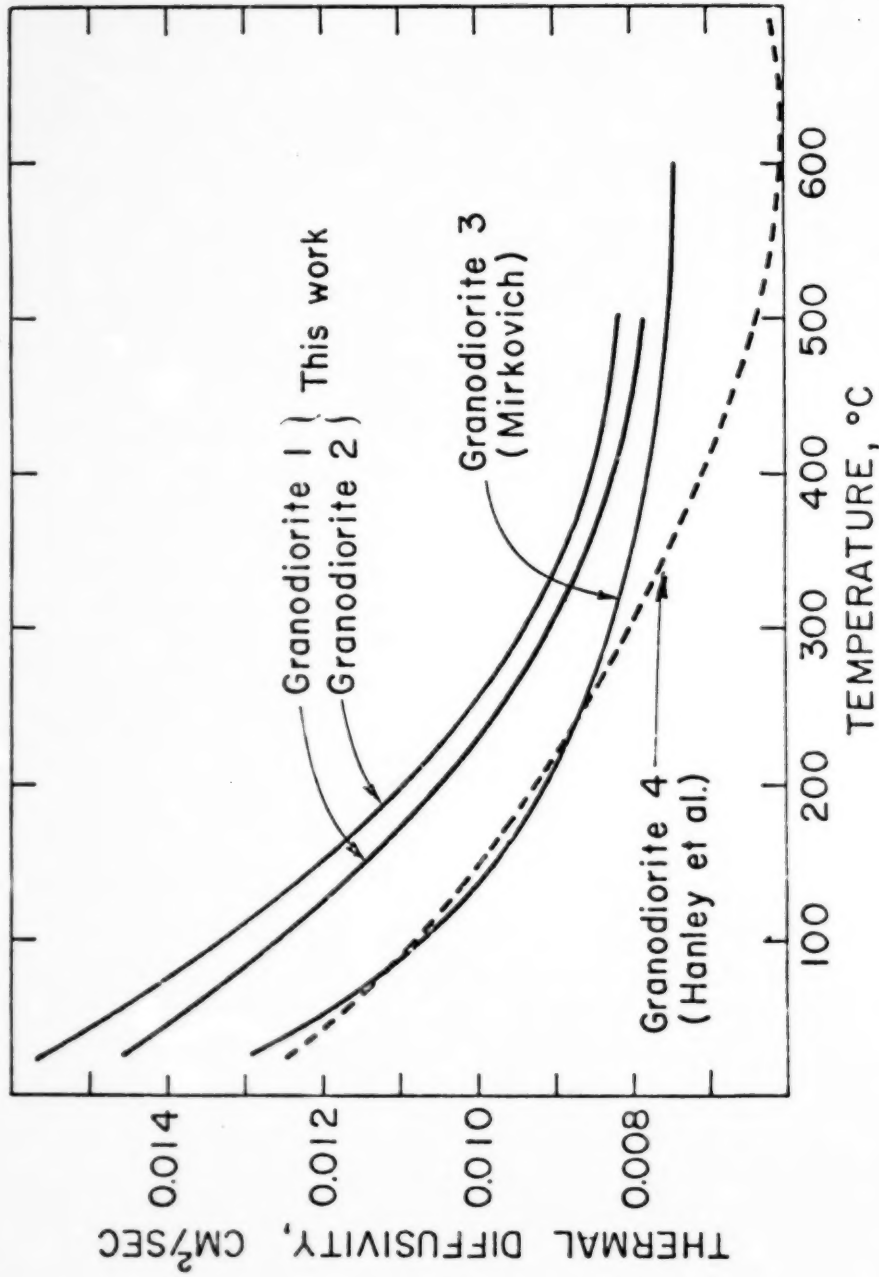


Figure 2. Comparison of thermal diffusivities of granodiorite from Nevada test site and from two other sources.

content. The quartz content of the L.L.L. granodiorite is 22% whereas that of reference (5) is 19%. The steeper decrease of thermal diffusivity with increasing temperature is also characteristic of higher quartz content. At temperature above 300°C the thermal diffusivities of specimens 1, 2 and 3 tend to level off with increasing temperature, whereas the thermal diffusivity of specimen 4 continues to decrease at nearly constant rate up to 500-600°C. As discussed in a previous study⁽⁵⁾, this behaviour could have been caused by either the mineralogical and textural nature of rock 4 or by the flash laser measuring method used by Hanley.

Thermal linear elongation of two L.L.L. granodiorite specimens is shown in Figure 3. As there is virtually no difference between the two samples, the values are represented by one curve, denoted "1 and 2", using the same notation as in Figure 1. Curve 3 in Figure 3 is the thermal elongation of a granodiorite specimen used in a previous study⁽⁵⁾, where it was shown that the thermal elongation of this particular specimen was the largest of all rocks investigated. Although at 500°C the thermal elongation of L.L.L. Specimens 1 and 2 is appreciably lower than that of Specimen 3, their overall thermal elongation is high, compared with many other rock types.

Rocks subjected to heat loads may spall. Therefore, when considering suitability of a rock type as a repository for nuclear waste, its tendency to spall should be evaluated. While there is no analytical quantitative method to incorporate the effect of various factors that contribute toward the thermal

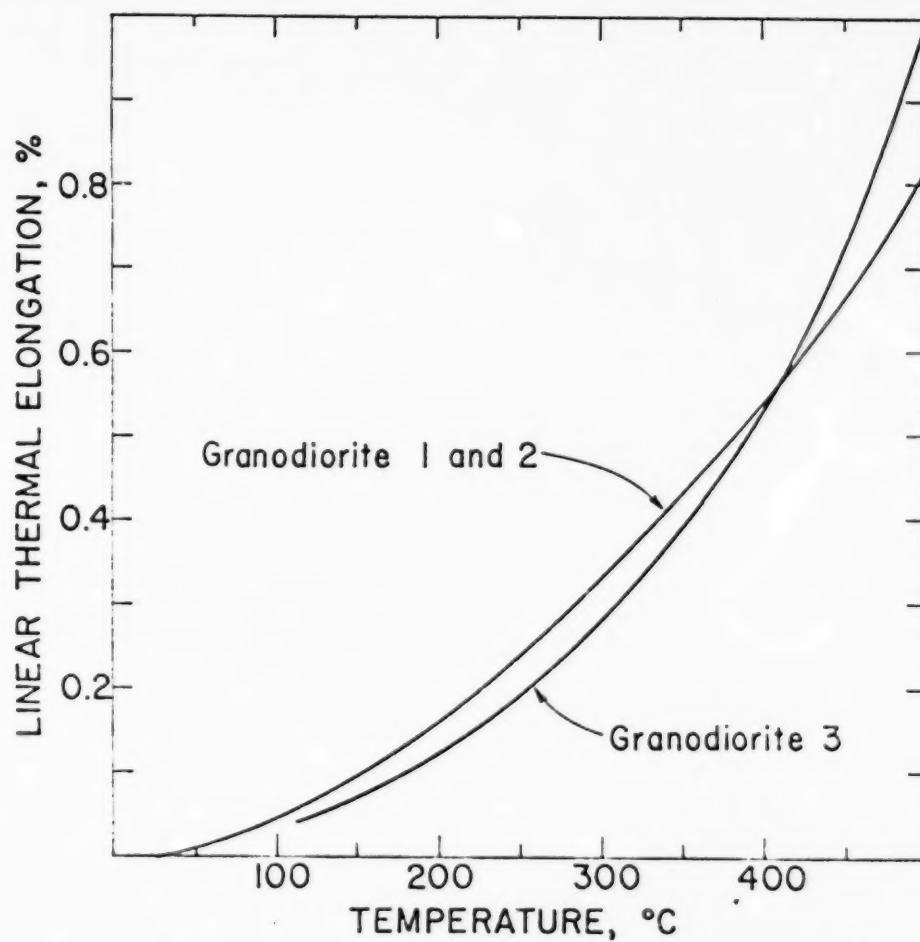


Figure 3. Linear thermal expansion of granodiorite specimens from Nevada test site (Curves 1 and 2) and of a granodiorite specimen (Curve 3) used in a previous study (Reference 5).

spalling of a rock, an empirical equation, which gives the high-temperature piercing rate of rocks and which could be used in this case as an indicator of rock spallability, was obtained by Mirkovich⁽⁷⁾. The piercing rate is:

$$R = 21.3 \alpha E - 1.75 \times 10^{-2}$$

where R is the piercing rate, cm/sec, α is thermal diffusivity, cm²/sec, and E is per cent elongation. The values for α are taken at 200°C and that of E at 500°C. Substituting in the above equation the values for L.L.L. granodiorite, i.e., $\alpha = 0.0108$ cm²/sec and $E = 0.825\%$, one obtains a piercing rate of 0.17 cm/sec. From previous experiences where it was found that the piercing rates of a variety of rock types ranged from 0.05 to 0.17 cm/sec, the piercing rate of the L.L.L. granodiorite appears to be quite high. From the point of view of spallability, therefore, this rock might not provide a satisfactory repository.

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